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1. Your reference — P21397/ACO/MVE/JAL

2. Patent application number — 9823463.6
(The Patent Office will fill in this part) — 28 OCT 1998

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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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Patents ADP number *(if you know it)* — 4118527001

If the applicant is a corporate body, give the country/state of its incorporation — United Kingdom

4. Title of the invention — "Survey Apparatus and Method"

5. Name of your agent *(if you have one)* — Murgitroyd & Company

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

373 Scotland Street
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Patents ADP number *(if you know it)* — 1198013

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

"Survey Apparatus and Method"

The present invention relates to survey apparatus and method.

Conventional survey equipment typically measures the distance, bearing and inclination angle to a target (such as a tree, electricity pylon or the like) or a target area, with reference to the position of a user. While this information is useful, it would be advantageous to create a three-dimensional (3D) image of the target.

In addition, conventional sighting devices which are used to select a target to be surveyed often result in false surveys being made as the target is often not correctly identified.

According to a first aspect of the present invention there is provided survey apparatus comprising a camera, a range finder, and an image processor capable of receiving and processing image and range signals to construct a three-dimensional image from said signals.

According to a second aspect of the present invention

there is provided a method of generating a three-dimensional image of a target area, the method comprising the steps of providing a camera, providing a range finder, selecting the target area to be surveyed using the camera, operating the camera to provide a captured image of the target area, and subsequently measuring the distance to each of a plurality of points by scanning the range finder at preset intervals relating to the points.

The camera is typically a digital video camera, and preferably a charge-coupled device (CCD) video camera. The apparatus typically includes a display device to allow a user to view a target area using the camera. The display device typically comprises a VGA eyepiece monitor, such as a liquid-crystal display (LCD) or flat panel display. The display device may alternatively comprise a VGA monitor. This offers the advantage that an image of the target may be viewed by the user to ensure that the correct target has been selected. Also, the survey apparatus may be operated remotely using the camera to view the target area.

The image is preferably digitised. Preferably, each of the points relates to a pixel in the digitised image.

Typically, the range finder is preferably a laser range finder. Preferably, the laser range finder is bore-sighted with the camera. This, in conjunction with the eyepiece monitor used to identify the target area, offers the advantage that the user can be sure that the target area he has selected will be captured by the camera. In addition, any subsequent calculations made by the image processor do not require an offset between the camera and the range finder to be considered.

Preferably, the survey apparatus includes a compass and an inclinometer and/or gyroscope. These allow the bearing and angle of inclination to the target to be measured. These are preferably digitised to provide data to the image processor.

Optionally, the survey apparatus further includes a position fixing system for identifying the geographical position of the apparatus. The position fixing system is preferably a Global Positioning System (GPS) which typically includes a Differential Global Positioning System (DGPS). This provides the advantage that the approximate position of the user can be recorded (and thus the position of the target using the measurements from the range finder and compass, where used. Preferably, the GPS/DGPS facilitates the time of the survey to be recorded.

The survey apparatus is typically mounted on a mounting device. The mounting device typically comprises headgear which may be worn on the head of a user. The headgear typically comprises a hard-hat type helmet. Alternatively, the survey apparatus may be housed within a housing. The housing is typically a hand-held device. Optionally, the mounting device may be a tripod stand or a platform which forms part of an elevation system, wherein the survey apparatus is elevated to allow larger areas to be surveyed.

Optionally, the apparatus may be operated by remote control.

The compass is preferably a digital fluxgate compass.

The survey apparatus is typically controlled by an input device. The input device is typically used to

activate the surveying apparatus, and may be a keyboard, keypad, penpad or the like. Typically, the input device facilitates operation of a particular function of the apparatus. The input device is typically interfaced to the processor via a standard keyboard input.

The GPS/DGPS is preferably integrally moulded within the helmet.

Preferably, the method includes the additional step of correlating the position of the pixels in the digital picture with the measured distance to each pixel. This generates a set of x, y and z co-ordinates for all of the pixel points which may be used to generate a three dimensional image of the target area.

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

Fig. 1 is a schematic diagram of a survey apparatus in accordance with the present invention;
Fig. 2 is a schematic view of a first embodiment of a mounting device for mounting the apparatus of Fig. 1;
Fig. 3 is an exemplary screen capture showing a typical output of the apparatus of Fig. 1;
Fig. 4 is a schematic view of a second embodiment of a mounting device;
Figs 5 to 9 show a hand-held housing for the survey apparatus of Fig. 1; and
Figs 10 to 12 show the housing of Figs 5 to 9 in use.

Referring to the drawings, Fig. 1 shows a schematic representation of a survey apparatus 10 in accordance with the present invention. The apparatus 10 includes a laser 12 which generates a beam of laser light 14. The beam 14 is reflected by a part-silvered prism 16 in a first direction substantially perpendicular to the direction of the initial beam 14, thereby creating a transmit beam 18.

The transmit beam 18 enters a series of transmitter optics 20 which collimates the transmit beam 18 into a target beam 22. The target beam 22 is reflected by a target (schematically shown in Fig. 1 as 24) and is returned as a reflected beam 26. The reflected beam 26 is collected by a series of receiver optics 28 and directs it to a laser light detector 30. The axes of the transmit and receiver optics 20, 28 are calibrated to be coincident at infinity.

Signals from the detector 30 are sent to a processor (not shown) which calculates the distance from the apparatus 10 to the target 24 using a time-of-flight principle. Thus, by dividing the time taken for the light to reach the target 24 and be reflected back to the detector 30 by two, the distance to the target 24 may be calculated.

The laser 12 is typically an invisible, eyesafe, gallium arsenide (GaAs) diode laser. The laser 12 is typically externally triggered and is designed to measure up to 200 metres to non-reflective targets.

Bore-sighted with the laser 12 (using the part-silvered prism 16) is a digital video camera 32. The camera 32 is preferably a complementary metal-oxide silicon (CMOS) camera which is formed on a silicon chip. The

chip generally includes all the necessary drive circuitry for the camera.

The transmit optics 20 serve a dual purpose and act as a lens for the camera 32. Thus, light which enters the transmit optics 20 is collimated and directed to the camera 32 (shown schematically at 34) thereby producing an image of the target 24 at the camera 32. The image which the camera 32 receives is digitised and sent to a processor (not shown).

In use, the apparatus 10 is typically externally triggered by an input device such as a push button, keyboard, penpad or the like. When the apparatus is triggered, the camera 32 captures a digitised image of the target area. The digitised image is made up of a plurality of pixels, the exact number of which is dependent upon the size of the image produced by the camera. Each pixel has an associated x and y co-ordinate which relate to individual positions in the target area. The processor is then used to sequentially scan the laser 12 (by moving the part-silvered prism 16 accordingly) to measure the distance to each successive point in the target area given by the x and y co-ordinates of the digitised image. This gives three-dimensional co-ordinates (ie x, y and z) to allow a three-dimensional image of the target area to be produced.

Fig. 2 shows a first embodiment of a mounting device for the surveying apparatus generally designated 110. The apparatus 110 includes a hard-hat type helmet 112. The helmet 112 may be replaced by any suitable headgear, but is used to give a user 114 some form of protection. This is advantageous where the user 114 is working in hazardous conditions, such as on a building

site. The helmet 112 is held in place on the head of the user 114 using a chin strap 116.

Mounted within the helmet 112, and preferably integrally moulded therein, is a Global Positioning System (GPS) 118. The GPS 118 is a system which provides a three-dimensional position of the GPS receiver (in this case mounted within the helmet 112 on the user 114) and thus the position of the user 114. The GPS 118 is used to calculate the position of the user 114 anywhere in the world to within approximately ± 25 metres. The DGPS calculates the position of the user 114 locally using radio/satellite broadcasts which send differential correction signals to ± 1 metre. The GPS 118 can also be used to record the time of all measured data to 1 microsecond.

The GPS 118 is coupled to a computer via a serial port. The computer may be located in a backpack 120, shown schematically in Fig. 6, or may be a portable computer, such as a laptop. The backpack 120 has a power source, such as a battery pack 122, either formed integrally therewith, or as an external unit.

Mounted on the helmet 112 is a housing 124 which encloses the range finder (as shown in Fig. 1), the video camera 32, an inclinometer (not shown) and a fluxgate compass (not shown). Signals from the range finder, camera 32, compass and inclinometer are fed to the computer in the backpack 120 via a wire harness 126.

The fluxgate compass generates a signal which gives a bearing to the target 24 and the inclinometer generates a signal which gives the incline angle to the target 24. These signals are preferably digitised so that

they are in a machine-readable form for direct manipulation by the computer.

The video camera 32 is preferably a charge-coupled device (CCD) camera. This type of camera operates digitally and allows it to be directly interfaced to the computer in the backpack 120. Signals from the camera 32 are typically input to the computer via a video card. The camera 32 may be, for example, a six-times magnification, monochrome camera with laser transmitter optics.

The view from the camera 32 is displayed on an eyepiece VGA monitor 128 suspended from the helmet 112. The monitor 128 is coupled to the computer in the backpack 120 via a second wire harness 130. The monitor 128 is used to display computer graphics and a generated graphics overlay. A sample screen shot as viewed on the monitor 128 is shown in Fig. 3.

The mounting of the monitor 128 on the helmet 112 is independent of the housing 124 and is thus adjustable to suit a plurality of individual users. A tri-axial alignment bracket (not shown) is provided for this purpose.

In use, software which is pre-loaded on the computer in the backpack 120 enables the user 114 to see a video image (provided by the camera 32) of the target on the monitor 128. As seen in Fig. 3, the software overlays the video image with a sighting graticule 160 and any measured data in a window 162.

It should be noted from Fig. 1 that the camera 32 and the laser range finder are bore-sighted. Conventional systems use an offset eyepiece sighting arrangement

with an axis which is aligned and collimated to be parallel to the axis of the laser range finder. However, use of the camera 32 (which displays an image of the target area on the VGA monitor eyepiece 128) bore-sighted with the laser range finder provides the user 114 with an exact view of the target area using the camera 32. Thus, there is no need for a collimated eyepiece and the user 114 can be sure that the range finder will be accurately directed at the target 24. To further improve accuracy, computer controlled graticule offsets may be generated during a calibration and collimation procedure to eliminate residual errors of alignment between the laser range finder and the camera 32. These offset values may be stored in an erasable-programmable-read-only-memory (EPROM) for repetitive use.

Operation of the apparatus 110 is controlled by an input device 130 connected to the computer via a keyboard input. The input device 130 typically comprises a keyboard, keypad, penpad or the like, and controls different functions of the apparatus 110.

When an observation or survey is required of a particular target area, the user 114 views the target area using the camera 32 and the eyepiece monitor 128. The target area is aligned with the graticule 160 (Fig. 3) using a small circle 164 as a guide.

The user 114 then fires the apparatus 110 using the input device 130. The computer initiates the camera 32 which captures a digital image of the target area and scans the laser 12 to provide a 3D image of the target area as previously described. In addition, measurements of the various parameters such as bearing and incline to the target area are recorded, digitised

and incorporated into the calculations made by the computer. The global position of the user 114 and the time of the measurement is also recorded from the GPS/DGPS 118.

The calculated and/or measured data is then sent from the computer to the monitor 128 and is displayed in the window 162 of the image by refreshing the data therein. This allows the user 114 to see the measured data and confirm that the correct target area has been identified and accurately shot by reference to the freeze frame image and the overlaid data window 162 and reticule 160.

The user 114 may then save either the data, image or both to the memory in the computer using an appropriate push button (not shown) on the input device 130. Multiple measurements of this nature may be recorded, thus giving 3D images of different target areas. These images may then be used to observe the target area either in real-time or later to assess and/or analyse any of the geographical features.

For example, one particular use would be by the military. During operations, a squad may be required to cross a river. The survey apparatus may be used to create multiple 3D images of possible crossing places. These would then be assessed to select the best location for a mobile bridge to be deployed. The image may be viewed locally or could be transmitted in a digital format to a command post or headquarters anywhere in the world. Use of the apparatus 110 would result in much faster and more accurate observations of the geographical locations and would avoid having to send soldiers into the area to visually assess the locations and report back. The apparatus may be

deployed on an elevated platform and operated by remote control to decrease the risk to human users in hostile situations.

Another application of the survey apparatus 110 would be to capture images of electricity pylons for example by targeting each individually and saving the data for future reference (for example to allow their positions on a map to be plotted or checked).

In addition to providing the 3D image of the target area, the computer may also calculate the position of the target area using the GPS/DGPS 118. The position of the user 114 is recorded using the GPS/DGPS 118, and by using the measurements such as bearing and inclination to the area, the position of the target area may thus be calculated.

The apparatus provides a 3D image of the target area which, in a geographical format, may be used to update map information and/or object dimensions and positions. The software may overlay and annotate the measured information on background maps which may be stored, for example, on compact-disc-read-only-memory (CD-ROM) or any other data base, such as Ordinance Survey maps.

Using a separate function on the input device 130, the user can change the image on the monitor 128 to show either a plot of the user's position (measured by the GPS/DGPS 118) superimposed on the retrieved data base map, or to view updated maps and/or object dimensions and positions derived from the measurements taken by the apparatus 110.

Fig. 4 shows a concept design of an alternative apparatus 200. The apparatus 200 is mounted on a head

band 212 which rests on the head of a user 214. Mounted on the headband 212 is a housing 224 which is attached to the headband 212. The housing 224 encloses the survey apparatus 10 (Fig. 1) as previously described. This particular embodiment incorporates an eyepiece monitor 250 into the housing 224.

Figs 5 to 9 show a hand-held housing for the survey apparatus. The hand-held device 300 includes an eyepiece 310 which is used to select the target area. Device 300 incudes a laser range finder similar to that shown schematically in Fig. 1, but without the video camera 32.

In use, a user 314 (Figs 10 to 12) puts the eyepiece 310 to his eye and visualises the target through a lens 312 (Fig. 7). When the target has been visualised, a fire button 314 is depressed which initiates the laser range finder to calculate the distance to the target using the time-of-flight technique. The distance to the target is then displayed on a display screen 316, which may be a liquid crystal display (LCD) for example. The transmit and receiver optics 320, 328 are located at the front of the device 300 (Fig. 7).

Where a 3D image is required, the device 300 may house the survey apparatus 10 (Fig. 1). A VGA monitor would replace the display screen 316 to allow a user to select the target area, and subsequently view the captured image from the camera 32. The eyepiece 310 would not be required as the camera 32 enables the user to select the target area. The device 300 would function in a similar manner to the apparatus 110. The 3D image may be stored in an image processor within the device 300 and subsequently downloaded for viewing. The device 300 may be provided with a suitable

interface for downloading, or may be provided with an alternative storage means such as an EPROM which may be removed from the device as required, or a floppy disc drive for example.

Thus there is provided a survey apparatus which is capable of producing 3D images in real time. The apparatus may be mounted in a hand-held device or on the head of a user. The apparatus may also be mounted on a tripod stand or on an elevated platform. Furthermore, the images may be stored or electronically transmitted for subsequent retrieval and analysis.

Modifications and improvements may be made to the foregoing without departing from the scope of the invention.

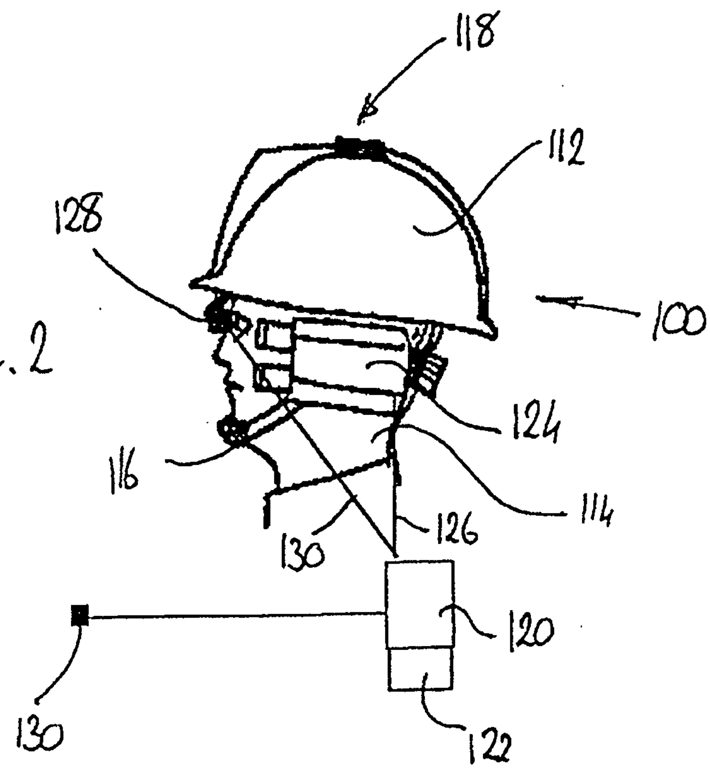

118
112
128
100
124
116
114
130
126
120
130
122

FIG. 2

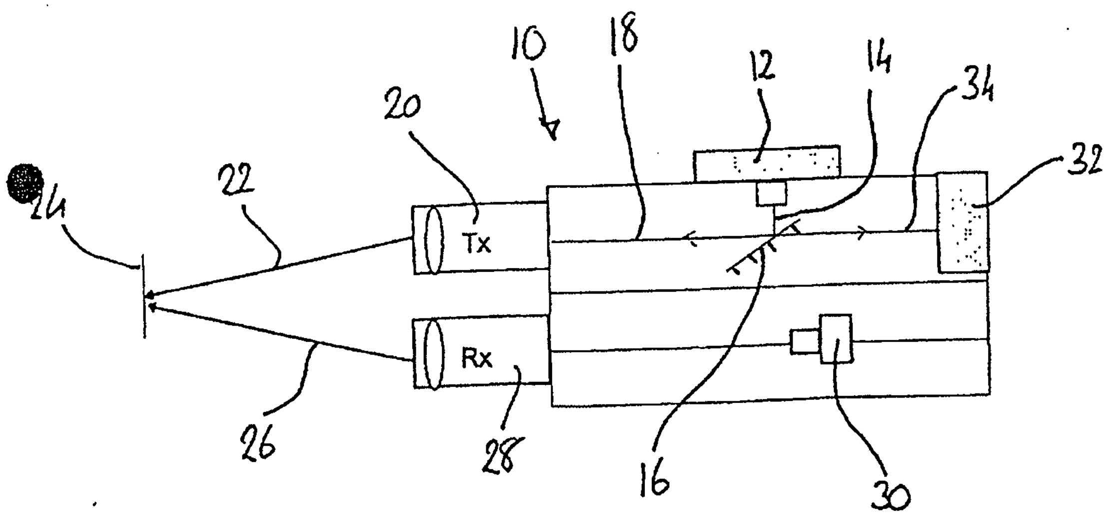

10
18
12
14
34
20
32
22
24
Tx
Rx
26
28
16
30

FIG. 1

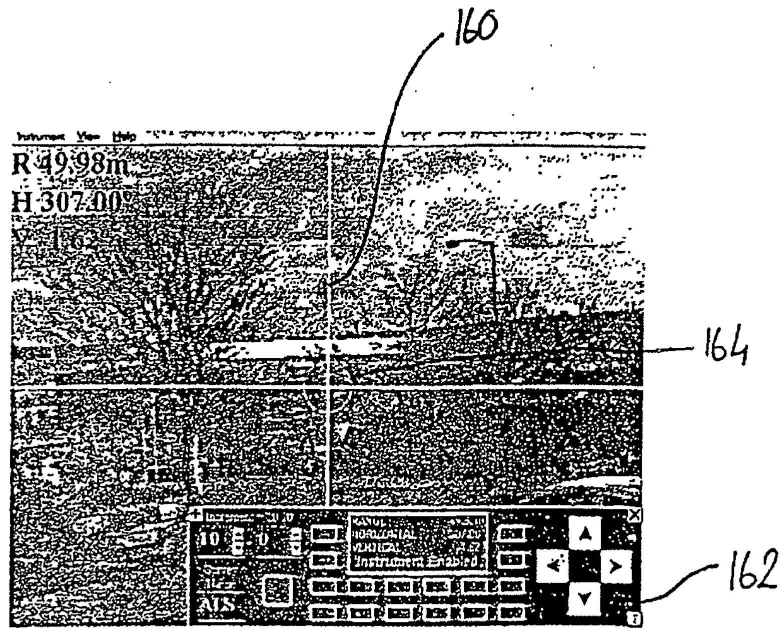


FIG. 3

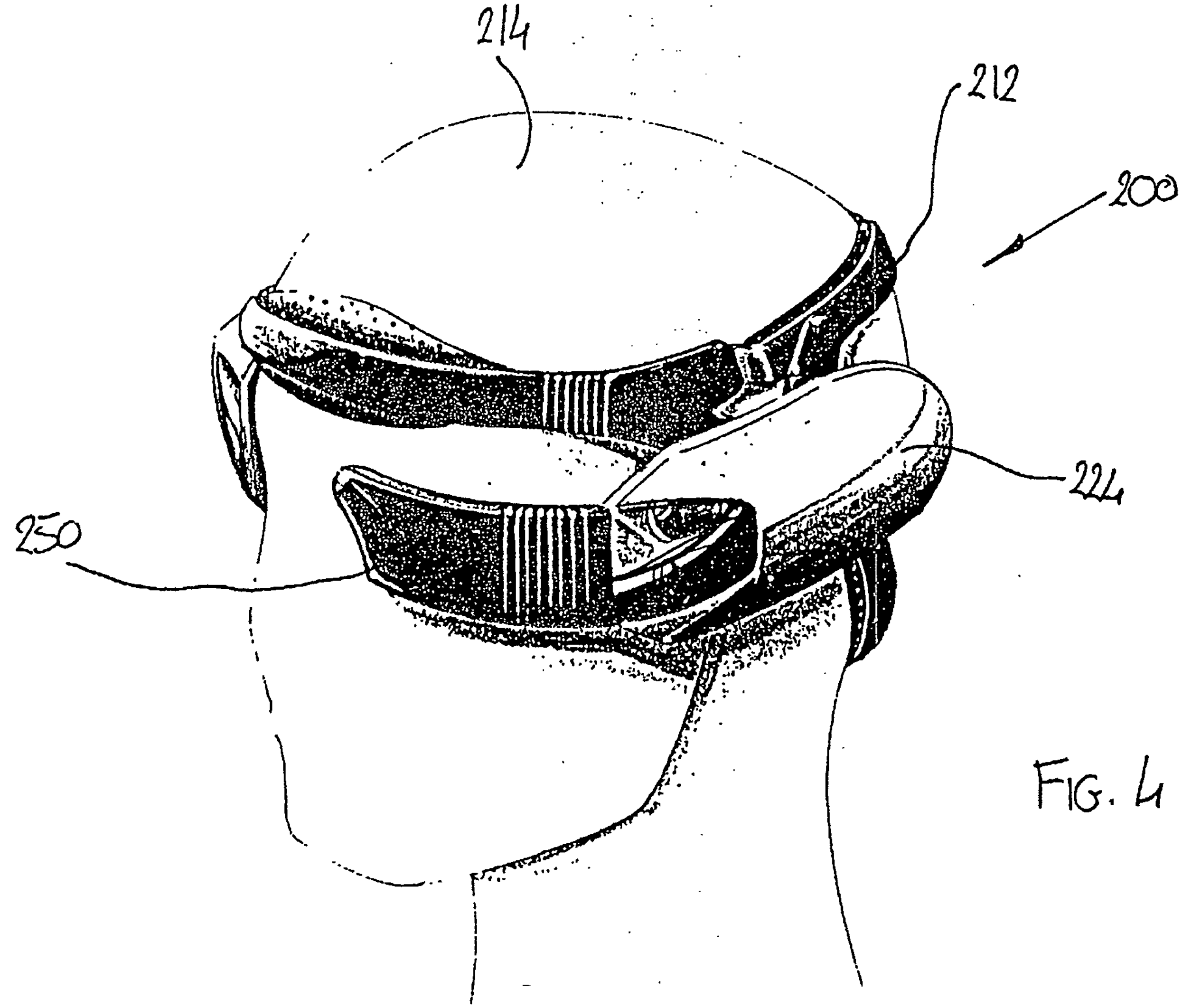


FIG. 4

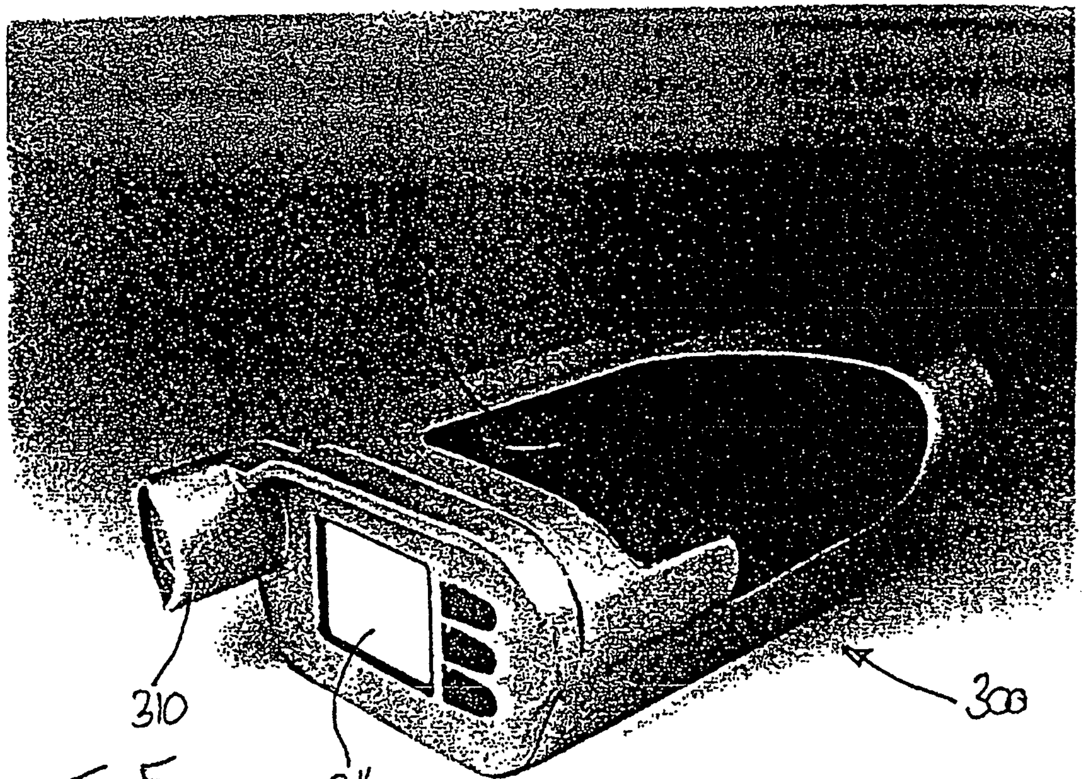


FIG 5

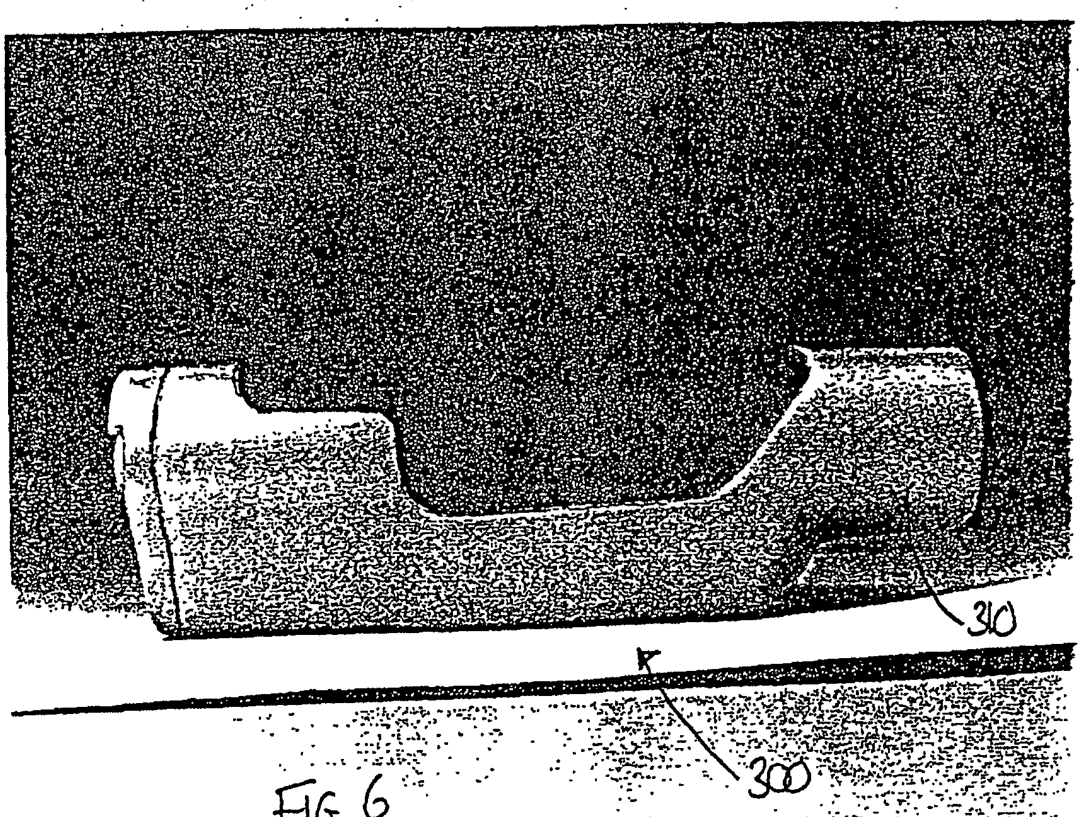


FIG 6

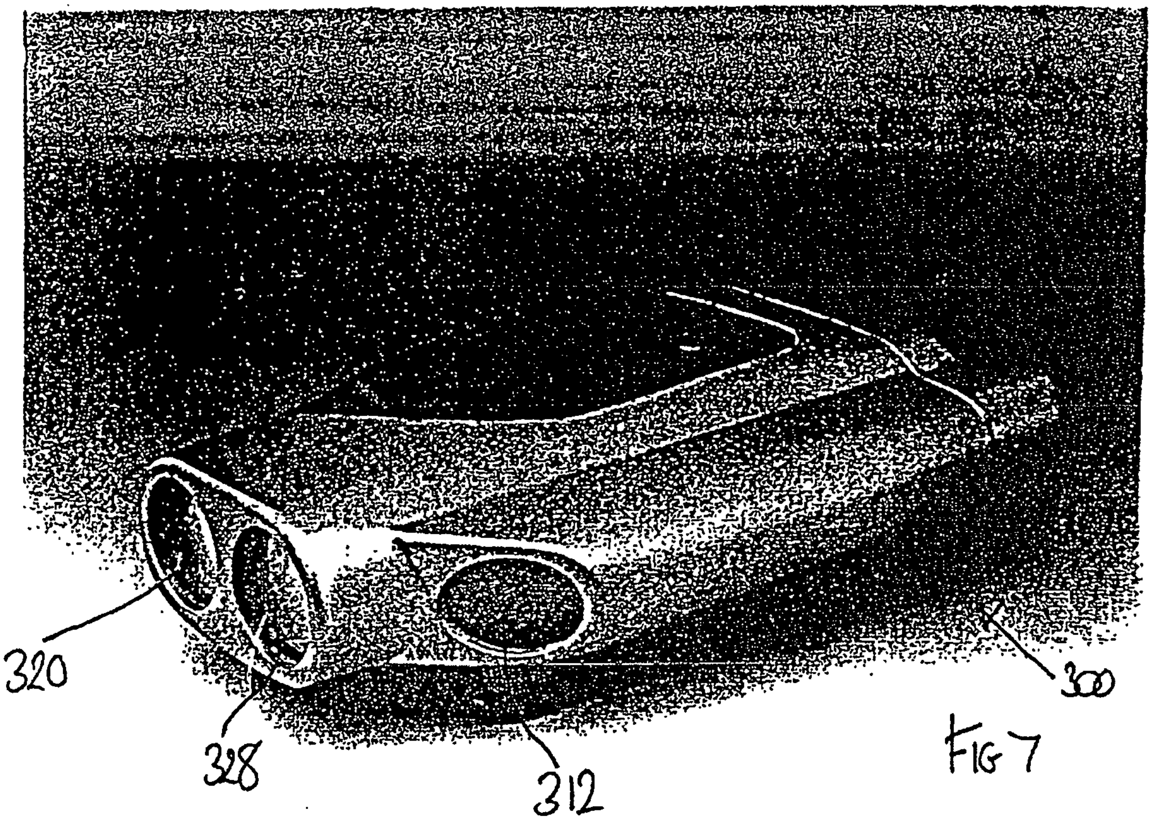


FIG 7

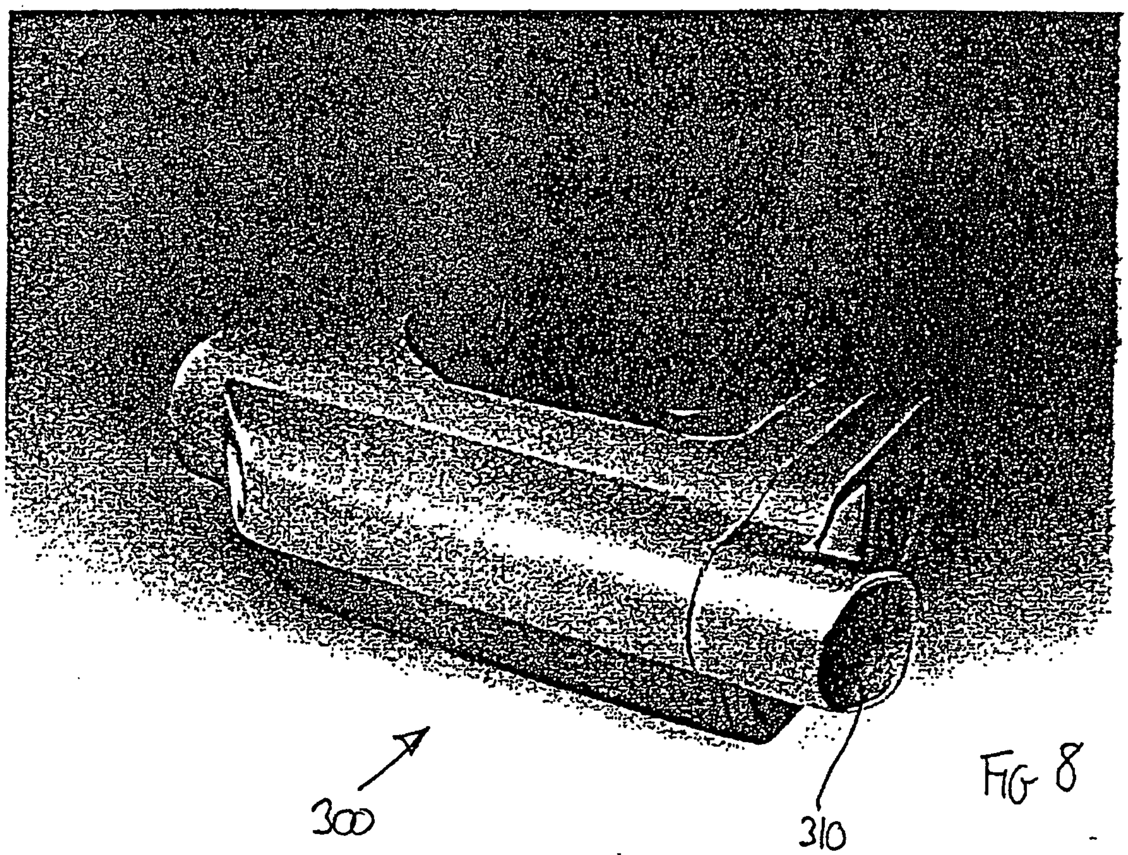
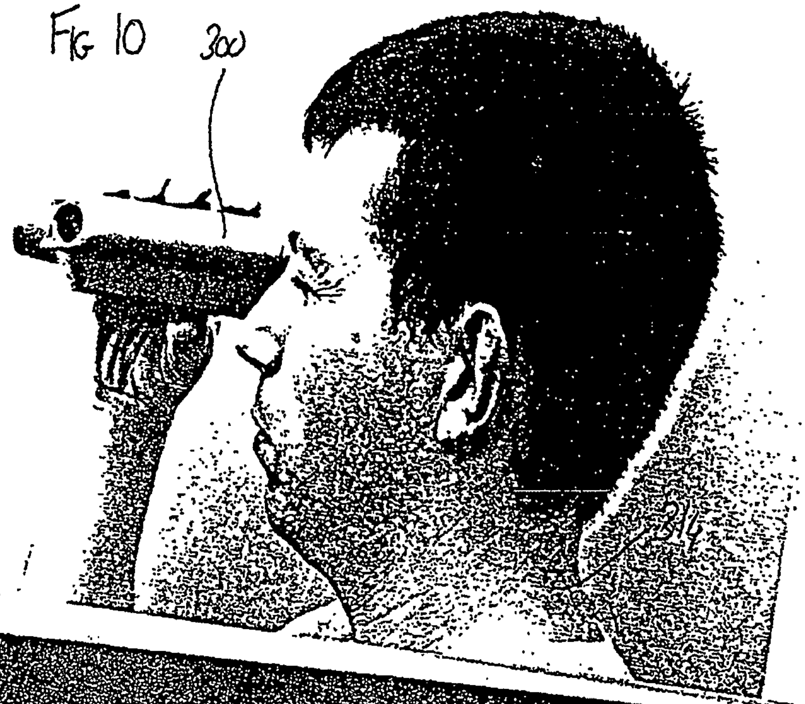


FIG 8

Fig 10



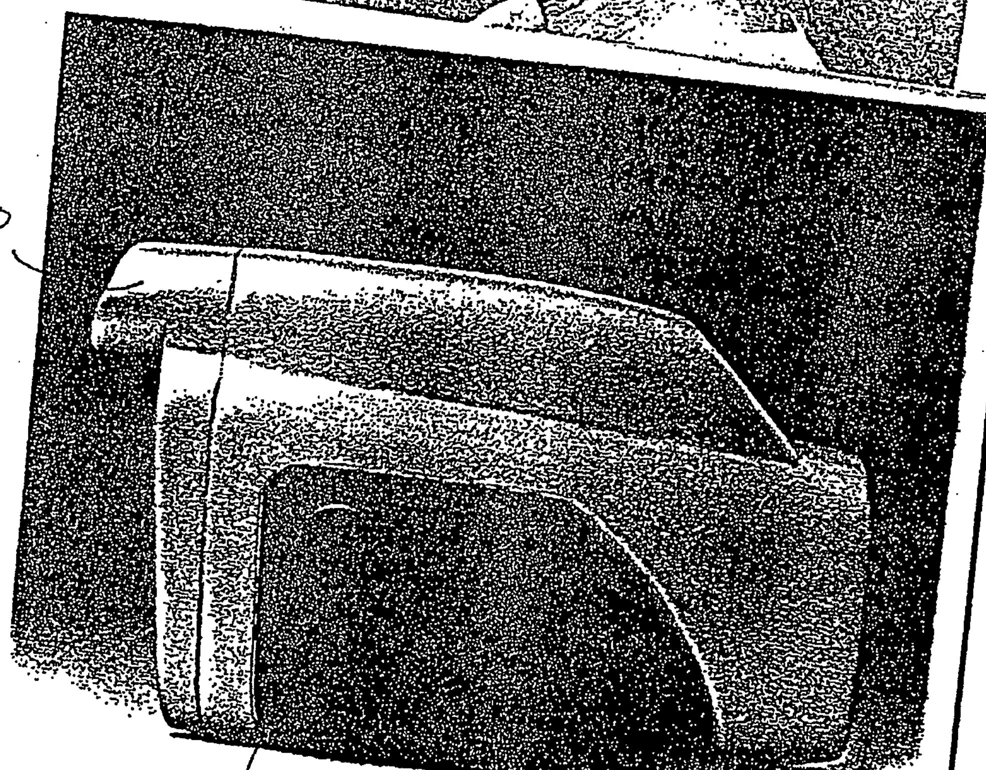


Fig 9

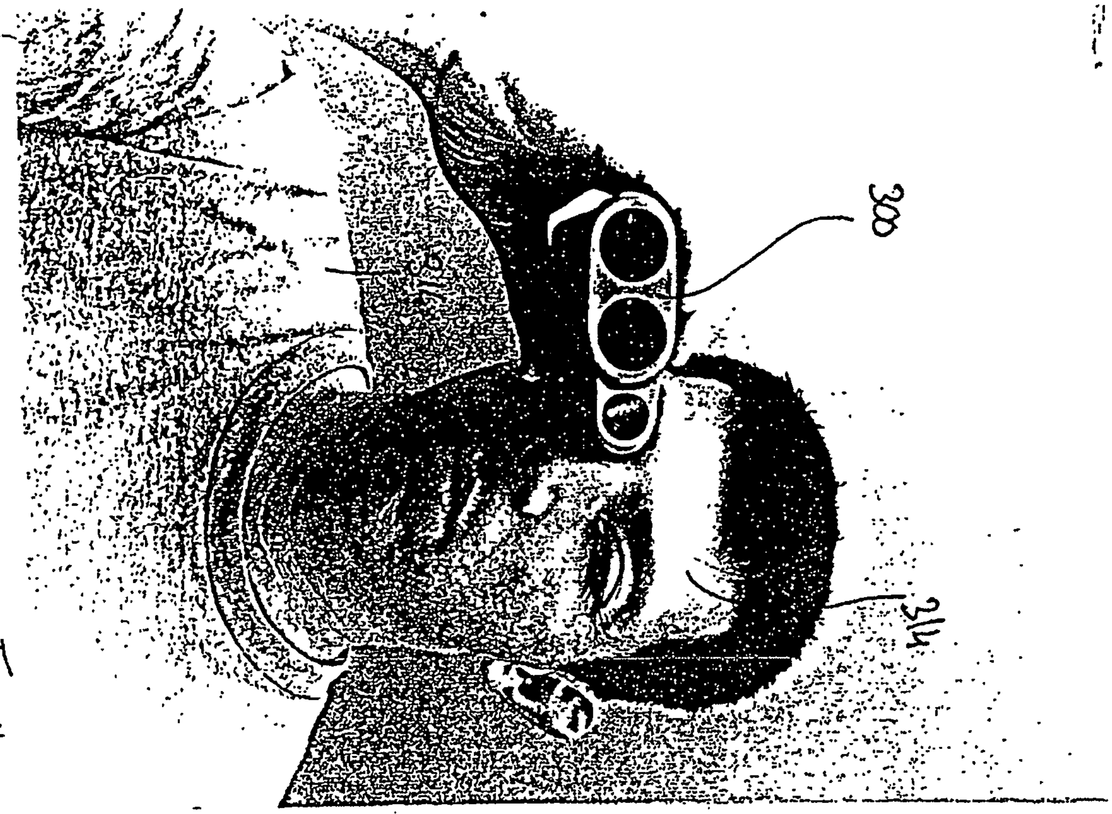


FIG 11

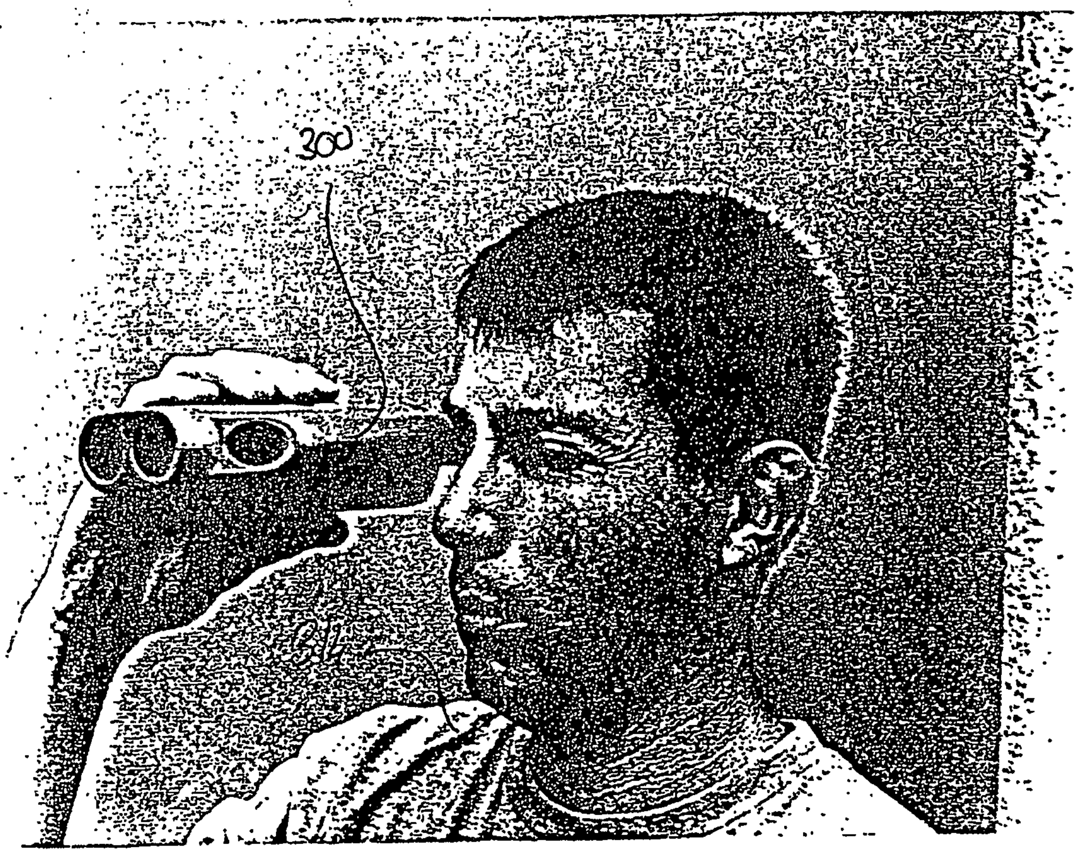


FIG 12